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**AN APPARATUS FOR USE IN A HIGH PRESSURE AND HIGH TEMPERATURE
REACTION SYSTEM, THE SYSTEM ITSELF AND A METHOD THEREIN**

TECHNICAL FIELD OF THE INVENTION

The present invention generally relates to an apparatus for
5 mitigation of corrosion in a high pressure and high temperature
reaction system, specifically in a system suitable for oxidative
waste treatment under supercritical water conditions. The
invention relates further to the reaction system itself and to a
method in said reaction system.

10 DESCRIPTION OF RELATED ART AND BACKGROUND OF THE INVENTION

Several approaches for disposing of waste are available today,
of which the major ones are landfilling and incineration. In
recent years, another technique based on supercritical water
oxidation (SCWO) has been commercialized, see, e.g.
15 Supercritical Water Oxidation Aims for Wastewater Cleanup, C.M.
Caruana, Chem. Eng. Prog., April 1995.

Supercritical water oxidation is a novel and advanced process
for, inter alia, effective destruction of toxic substances,
particularly organic pollutions, in wastewater and sludge. The
20 process converts, fast and effectively, organic materials
containing substantially carbon and hydrogen to carbon dioxide
and water, at a temperature above the critical point of water
(374°C and 22,13 MPa), while releasing energy. The process may
be completely contained and the destruction efficiency is often
25 higher than 99%.

Heavy metals present during the process are converted to their
oxides whereas sulfur and phosphorous are converted to sulfate
and phosphate, respectively. Halogens are converted to their
corresponding acids, e.g., hydrochloric acid. Smaller amounts of
30 nitrogen compounds, e.g. amines and ammonia, which exist in the

waste material flow, are converted to molecular nitrogen, and not to NO_x , which is an acidifying and fertilizing residual product and therefore undesirable in the effluent.

If, however, the waste material contains large amounts of ammonia and/or organic nitrogen compounds, substantial amounts of the nitrogen source may be found in the effluent as ammonia as a result of the destruction process. This phenomenon is undesirable as ammonia constitutes a fertilizing compound. Besides, discharge of ammonia without further purifying is very often imposed with restrictions.

It is known in the literature, e.g. through *Reactions of Nitrate Salts with Ammonia in Supercritical Water*, P.C. Dell'Orco et al., *Ind. Eng. Chem.*, Vol. 36, No. 7, 1997, and references therein, that ammonia can be converted to molecular nitrogen during supercritical water oxidation conditions if nitric acid is used as a co-oxidant together with molecular oxygen, hydrogen peroxide or another suitable compound. The nitric acid has preferably to be supplied to the waste material flow firstly after that the organic contents have been destructed with oxygen as nitrate otherwise will compete with oxygen in the destruction of the organic contents. Furthermore, the nitric acid has to be dosed with high accuracy relative to the amount of ammonia (a stoichiometric amount is needed). If too little nitric acid is supplied, a remaining amount of ammonia will be left whereas too large amounts of nitric acid will result in an excess of nitrate in the effluent.

For purposes of strength and corrosion, nickel-based alloys, such as Hastelloy or Inconel, are employed for manufacturing of equipment for SCWO. Acids, and not at least nitric acid, are, however, in presence of oxygen strongly corrosive at high temperatures, though still subcritical ones, even if these corrosion resistant nickel alloys are used, see, e.g. *The Corrosion of Nickel-base Alloy 625 in Sub- and Supercritical*

Aqueous Solutions of HNO_3 in the Presence of Oxygen, P. Kritzer et al., J. Mater. Sci. Lett., 1999, in print, and references therein. It was found in the temperature-resolved corrosion measurements reported that the corrosion due to nitric acid was most severe at temperatures between about 270°C and 380°C , the same temperature range in which general corrosion is caused by the mixtures HCl/O_2 and $\text{H}_2\text{SO}_4/\text{O}_2$, respectively. At supercritical temperatures the corrosion rates were low.

For this reason, particular solutions must be employed for the entry of nitric acid into the supercritical wastewater flow containing ammonia or ammonium salts to avoid or at least minimize the corrosion.

However, as regards corrosion, generally the most troublesome compound in the supercritical water oxidation process is the chlorine element, since it is very common in various chemical substances. If the chlorine is present as an ion at elevated temperatures, it will corrode the construction materials mentioned above. The chlorine may have been an ion originally, liberated during heat up or in the reactor.

US 5,358,645 issued to Hong et al. disclose an apparatus and process for high temperature water oxidation, the apparatus (not in detail described) having a surface area, that may be exposed to corrosive material, composed of zirconia based ceramics. The ceramics may be employed as coatings or linings.

US 5,461,648 issued to Nauflett et al. disclose a supercritical water oxidation reactor with a corrosion-resistant lining. The inner surface of the reactor vessel is coated with artificial ceramic or diamond. A cylindrical baffle for introducing the oxygenating agent extends axially within the interior of the vessel and has its exterior surface inside the vessel coated with said artificial ceramic or diamond.

US 5,552,039 issued to McBrayer, Jr. et al. disclose a turbulent flow cold-wall reactor. It mentions, inter alia, that if the atmosphere in the reaction chamber is harsh and corrosive, the inside wall of the reaction chamber should preferably be made of
5 or covered with a coating or a liner withstanding the harsh atmosphere.

None of these US patents, is, however, discussing corrosion problems in terms of temperature dependent corrosivity, or the particular corrosion caused by the corrosive compounds discussed
10 above.

SUMMARY OF THE INVENTION

It is consequently an object of the present invention to provide an apparatus for use in a high pressure and high temperature reaction system, specifically in a system suitable for oxidative
15 waste treatment under supercritical water conditions, that mitigates or eliminates the occurrence of corrosion.

It is a further object of the invention to provide such an apparatus that is effective, robust, and easy to install and of
low cost.

20 It is yet a further object of the invention to provide the apparatus in such a way that it is easily replaceable in the reaction system.

These objects among others are, according to one aspect of the invention, attained by an apparatus as claimed in Claim 1.

25 A further object of the present invention is to provide a method for disposing of waste using said apparatus.

Consequently, there is according to a second aspect of the present invention provided a method as claimed in Claim 22.

An advantage of the present invention is that it allows the main parts of the reaction system, including the reactor itself, to be constructed of a relatively inexpensive material such as nickel based and nickel-chromium alloys, and still use or be able to treat corrosive materials in the process.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description of embodiments of the present invention given hereinbelow and the accompanying Figs. 1-3 which are given by way of illustration only, and thus are not limitative of the invention.

Fig. 1 shows a simplified block diagram of a reaction system suitable for oxidative waste treatment under supercritical water conditions wherein the present invention may be employed.

Fig. 2 shows, in cross-section, a first embodiment of an apparatus according to the present invention.

Fig. 3 shows, in cross-section, a second embodiment of an apparatus according to the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

In the following description, for purposes of explanation and not limitation, specific details are set fourth, such as particular hardware, applications, techniques, etc. in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the present invention may be practiced in other embodiments that depart from these specific details. In other instances, detailed descriptions of well-known methods, protocols, apparatus, and circuits are omitted so as not to obscure the description of the present invention with unnecessary details.

Considering Fig. 1, the operation of a high pressure and high temperature reaction system 10 such as a system suitable for oxidative waste treatment under supercritical water conditions, will briefly be overviewed so that in the subsequent detailed description of the present invention, the operation of the inventive apparatus may be better understood.

A conventional reaction system 10 comprises a primary tank 12, a heat exchanger 14, a heater 16 and a reaction chamber 18. A primary wastewater stream 20 passes initially through the first compartment (not shown) of the heat exchanger 14, then through the heater 16, and enters the reaction chamber 18 under pressure, after it has been mixed with oxidant coming through feed line 22. The organic matter contained in the primary waste stream 20 is oxidized, and in sequence, the hot effluence passes through the second compartment (not shown) of the heat exchanger 14. As well known, heat exchangers usually have two compartments, physically isolated from each other, which, however, are heat-communicating. The second compartment transfers heat to the first compartment.

Constructing materials for the reactor and the tubing may comprise steel, nickel-based alloys, platinum, gold, titanium, zirconium, ceramics, ceramic composites and other corrosion resistant materials as the environment inside the reaction chamber and tubing may be hostile and corrosive. However, as many of the latter materials are highly expensive, an optimal compromise between cost, on one hand, and corrosion resistance, on the other hand, is to use nickel based alloys such as Hastelloy or Inconel, for the manufacturing of such equipment.

As already discussed in the prior art, there is a number of species that are very aggressive relative to these nickel based alloys within a finite temperature range, among them nitric acid, sulfuric acid and hydrochloric acid. All these three acids are strongly corrosive between about 270 and 380°C, but the

corrosion rates for the latter two acids are lower by a factor of ten than the one found for nitric acid, see said Kritzer article.

It is clear from the description above of the operation of the system that the wastewater flow, as well as any additives, will be heated from initial low temperatures, which probably are close to ambient temperatures, up to supercritical temperatures (above 374°C) for the oxidative treatment of the waste, whereafter the effluent is cooled either in a heat exchanger or by mixing it with quench water or a combination of both.

The present inventors have realized that if the initial temperatures and the temperature of the cooled effluent are kept preferably well below 270°C and the temperature in the reaction chamber is kept preferably above 380°C, there is generally only two sections of a reaction system made of nickel-based alloy that may be attacked by corrosive agents such as those mentioned above contained in, or supplied to, the wastewater flow, namely a "heating" section and a "cooling" section, where the temperatures are within the temperature interval of said corrosion.

The present invention is thus concerned with such sections of the reaction system and how to design them in order to provide a reaction system of low cost and good corrosion resistance. The idea is to provide appropriate tubing (made of nickel based alloy or other, preferably relatively inexpensive, material that is not corrosive resistant) of the system with a corrosive resistant tube or liner. The number of tubes or liners, their positions and their lengths are chosen in order to protect the system from corroding.

Hereinbelow will follow a few implementation examples of the present invention. Note that the terms "corrosive" and "corrosive-resistant material" as used in the description below

and in the appended claims should be understood as "corrosive" relative conventional construction material for high pressure and high temperature reaction systems suitable for supercritical water oxidation such as steel, nickel based alloys, nickel-chromium alloys and the like, at least within a given temperature interval, and "corrosive-resistant material" refers to unconventional expensive material which is corrosion-resistant relative a wide variety of harsh media such as acids, particularly the acids discussed above, halogens and the like, respectively. Examples of corrosion-resistant materials will be given below.

A first embodiment of the present invention, shown in Fig. 2, depicts an apparatus 101 for introducing nitric acid in a supercritical water flow containing ammonia or ammonium with the purpose of converting this to molecular nitrogen.

In a section of a reaction system tube 103, which preferably is the conduit between the heater 16 and the reaction chamber 18, or part of the reaction chamber itself, of Fig. 1, a separate tube or liner 105 of a corrosion resistant material is mounted, the outer surface of which is in fit with the inner surface of reaction system tube 103. Alternatively, tube 105 constitutes part of the reaction system tube 103 itself (not shown).

A feeding pipe 107 of relatively small diameter, is mounted through an opening of tube 103 and extends substantially axially with tube 103 and liner 105, and which ends in the interior of tube 103. Preferably, feeding pipe 107 and tube 103 are concentrically arranged for transportation of fluids, the former nitric acid and the latter preheated wastewater feed, in the same directions, as indicated by arrows 109-113. The temperature of the wastewater should preferably be above 380°C, and the temperature of the nitric acid should be low, preferably considerably lower than 270°C. Note that if the concentration of the corrosive agent is low, these temperature limits are not

very crucial, i.e., the corrosion would be low at temperatures slightly lower than 380°C and, particularly, at temperatures slightly higher than 270°C, e.g., 300°C.

By pumping nitric acid through the feeding pipe it will be preheated by the hot water flow and then get mixed with the supercritical water. The flow rates are such that the total flow (wastewater and nitric acid) becomes supercritical with a temperature of above 380°C after having reached a steady temperature state a certain distance 115 from the end of the feeding pipe, said distance being referred to as the heat transfer or mixing length. Accordingly, to avoid any risk of corrosion of the inner walls of tube 103, the length of the liner 105 should be of at least this length, and it should be localized to protect the inner walls of tube 103 within this length. For practical reasons, the liner 105 may have an offset 117 in the end facing the end of the feeding pipe, i.e. extend beyond (upstream of) said feeding pipe end to avoid any risk of corrosion in that region.

The material of the liner and preferably of the feeding pipe is chosen according to its corrosion resistance relative nitric acid at the occurring temperatures. Literature data shows that titanium, generally, is a suitable material, but also materials such as zirconium, platinum, tantalum, niobium and ceramics may be chosen. The entire liner, or an inner coating thereof, may be constructed of such material.

Even if a limited degree of corrosion may exist using these materials, the components are relatively cheap and easy to replace when so needed.

Preferably, there are means for positioning and/or holding the liner in place. In the embodiment showed, tube 103 is provided with an elbow at the downstream end of the mixing length to prevent liner 105 from moving further downstream. However, any

suitable means for positioning and/or holding the liner, e.g. flanges at the inner walls of tube 103, may be used.

In experimental work, an injection apparatus as the one shown in Fig. 2, was used, the liner and the feeding pipe being made of titanium. The ammonia destruction was performed by pumping 65% nitric acid into the reaction system during several hours without any detected corrosion. When the liner and the feeding pipe were demounted and inspected no corrosion of these components was discovered. In contrast thereto, in an experiment in which nitric acid was pumped into a supercritical water flow containing ammonia through a T-pipe of Inconel 625, the pipe was destroyed through corrosion in just a few hours.

Consequently, by using an injection apparatus according to Fig. 2, nitric acid may safely be introduced without severe corrosion of the reaction system.

Furthermore, a substantial portion of the reaction between nitric acid and ammonia and/or ammonium will take part as early as in the section of the reaction system where the liner is localized, which further reduces the risk for severe corrosion.

Alternatively, feeding pipe 107 and tube 103 of Fig. 2 may be arranged for transportation of a wastewater feed containing a corrosive agent such as a halogen, and water or a wastewater feed in lack of such a corrosive agent, respectively. The water or wastewater in tube 103 is preferably at a supercritical temperature, whereas the corrosive wastewater may be cooler.

Referring next to Fig. 3, which illustrates an apparatus 201 according to a second embodiment of the present invention, a separate tube or liner 205 of a corrosion resistant material is mounted in a section of a reaction system tube 203, which is preferably at the effluent output or elsewhere in the exit path tubing. The outer surface of liner 205 is arranged to be in fit with the inner surface of the reaction system tube 203.

A first input tube 207, is mounted through an opening of tube 203 and extends substantially axially, preferably concentrically, with tube 203 and liner 205, and which ends in the interior of tube 203. A second input tube 208 is connected to tube 203 upstream from said end of input tube 207.

Input tube 207 and input tube 208 are arranged for transporting effluent from reactor 18 containing corrosive compounds such as nitric acid, sulfur acid, or the like, and quench water, respectively, in the directions as indicated by arrows 209-213.

10 The effluent stream is supercritical or close to supercritical, and the temperature of the quench water is low, preferably at ambient temperature.

By pumping appropriate amounts of quench water through input tube 208, the effluent input through tube 207 will be cooled effectively by the quench water and get mixed with it. The flow rates are such that the total flow (effluent and quench water) will have a temperature of below a certain temperature, e.g. 270°C, depending on concentration of corrosive compounds, after having reached a steady temperature state a certain distance 215 from the end of the input tube 207, said distance being referred to as the mixing length. Accordingly, to avoid any risk of corrosion of the inner walls of tube 203, the length of the liner 205 should be at least of this mixing length, and it should be localized to protect the inner walls of tube 203 within this length. For practical reasons, the liner 203 may have an offset 217 in the end facing the end of tube 207, i.e. extend beyond (upstream of) said tube end, to avoid any risk of corrosion in that region.

The material of the liner and preferably of tube 207, as well as suitable means for positioning and/or holding the liner in place may be chosen as in the first embodiment.

The first and the second embodiments of the present invention may be modified to include a heat exchange for assisting in increasing or decreasing the temperature in tubes 103 and 203, respectively. Hereby, the lengths of liners 105 and 205, respectively, may be shortened.

As a further example of an implementation of the present invention (not illustrated in the drawings), an effluent from the reactor containing chlorine ions is pre-cooled in a heat exchanger by part of the incoming waste stream, to a temperature well above 380°C, e.g., 400°C. The effluent is then cooled by an apparatus according to the present invention to a sufficient low temperature, e.g., 260°C, to minimize corrosion. After leaving the apparatus, the effluent water mixture is further cooled by the remaining of the waste stream.

It will be obvious that the invention may be varied in a plurality of ways. For instance, the geometry and function of the reaction system and the appearance of the tubing may deviate substantially from the description above. Such and other variations are not to be regarded as a departure from the scope of the invention. All such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the appended claims.

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CLAIMS

1. In a high pressure and high temperature reaction system suitable for oxidative waste treatment, particularly a reaction system for supercritical water oxidation (SCWO), an apparatus
5 (101, 201) for injecting (109, 209) a first fluid of a first temperature at a first flow rate into a second fluid of a second temperature at a second flow rate, said first fluid being corrosive in a temperature range which excludes said second temperature and includes said first temperature or which lies
10 between said first and second temperatures, characterized in
- a first conduit (107, 207) connected and adapted to transport the first fluid,
- a second conduit (103, 203) connected and adapted to transport
15 the second fluid, said first conduit (107, 207) ending in the interior of said second conduit (103, 203), thus communicating with said second conduit, whereby mixture of, and a predetermined amount of heat transfer between, the first and the second fluids are arranged to occur within a mixing length (115,
20 215) in said second conduit (103, 203),
- a tube or liner (105, 205) with at least its inner surface area of a corrosion resistant material, said tube or liner being located in, or constituting part of, said second conduit and extending along said mixing length (115, 215) to protect said
25 second conduit from corroding, and
- the first and second temperatures and the first and second flow rates being arranged so that a third temperature of the mixed fluids downstream said mixing length (115, 215) is obtained, at which said third fluid being substantially non-
30 corrosive.
2. The apparatus as claimed in Claim 1, characterized in that at least the inner surface area of said first conduit (107, 207) is of a corrosion resistant material.

3. The apparatus as claimed in Claim 2, characterized in that said first fluid is corrosive at said first temperature.

4. The apparatus as claimed in any of Claims 1-3, characterized in that said first fluid contains an acid.

5. The apparatus as claimed in any of Claims 1-4, characterized in that said second and third temperatures are higher than said temperature range in which said first fluid is corrosive.

6. The apparatus as claimed in Claim 5, characterized in that said second fluid contains supercritical wastewater.

7. The apparatus as claimed in Claim 6, characterized in that the mixed fluids in said second conduit (103, 203) are fed to the reactor (18) of the high pressure and high temperature reaction system (10) for oxidation of waste material contained in the wastewater.

8. The apparatus as claimed in Claim 6, characterized in that said second conduit (103, 203) is part of the reactor (18) of the high pressure and high temperature reaction system, wherein waste material contained in the wastewater is oxidized.

9. The apparatus as claimed in any of Claims 5-8, characterized in that said first fluid contains nitric acid and that said second fluid contains nitrogenous compound.

10. The apparatus as claimed in any of Claims 5-9, characterized in that said first fluid contains sulfuric acid and/or hydrochloric acid.

11. The apparatus as claimed in any of Claims 1-4, characterized in that said second and third

temperatures are lower than said temperature range in which said first fluid is corrosive.

12. The apparatus as claimed in Claim 11, characterized in that said second fluid acts as cooling water.

5 13. The apparatus as claimed in Claims 11 or 12, characterized in that said first fluid contains destructed supercritical or subcritical wastewater output from the reactor (18) of the high pressure and high temperature reaction system (10).

10 14. The apparatus as claimed in Claim 13, characterized in that the mixed fluids in said second conduit (103, 203) are output from the high pressure and high temperature reaction system (10).

15 15. The apparatus as claimed in any of Claims 1-14, characterized in that the tube or liner (105, 205) is removably arranged in said second conduit.

16. The apparatus as claimed in any of Claims 1-15, characterized in that the tube or liner (105, 205) is extending a predetermined distance (117, 217) upstream from
20 where said first conduit (107, 207) ends.

17. The apparatus as claimed in any of Claims 1-16, characterized in that said second conduit is provided with means for holding and/or positioning the tube or liner (105, 205) in said second conduit (103, 203).

25 18. The apparatus as claimed in Claim 17, characterized in that said second conduit (103, 203) is provided with an elbow (119, 219) at the downstream end of the mixing length (115, 215) in order to prevent the tube or liner (105, 205) from moving along the inner surface of said second conduit (103, 203)
30 in the downstream direction.

19. The apparatus as claimed in any of Claims 1-18, characterized in that at least the inner surface area of the tube or liner (105, 205) is made of a material chosen from the group of titanium, zirconium, platinum, tantalum, niobium and alloys thereof.

20. The apparatus as claimed in Claim 19, characterized in that the entire tube or liner (105, 205) is made of a material chosen from the group of titanium, zirconium, platinum, tantalum, niobium and alloys thereof

21. A high pressure and high temperature reaction system suitable for oxidative waste treatment, particularly a reaction system for supercritical water oxidation (SCWO), characterized in that it comprises the apparatus as claimed in any of Claims 1-20.

22. In a high pressure and high temperature reaction system suitable for oxidative waste treatment, particularly a reaction system for supercritical water oxidation (SCWO), a method for injecting a first fluid of a first temperature at a first flow rate into a second fluid of a second temperature at a second flow rate, said first fluid being corrosive only in a temperature range which excludes said second temperature and includes said first temperature or which lies between said first and second temperatures, characterized by

- connecting and adapting a first conduit (107, 207) to transport the first fluid,
- connecting and adapting a second conduit (103, 203) to transport the second fluid,
- adapting said first conduit (107, 207) to end in the interior of said second conduit (103, 203), thus communicating with said second conduit,
- arranging mixture of, and a predetermined amount of heat transfer between, the first and the second fluids to occur within a mixing length (115, 215) in said second conduit,

- providing a tube or liner (105, 205) with at least its inner surface area of a corrosion resistant material, said tube or liner being located in, or constituting part of, said second conduit and extending along said mixing length (115, 215), to protect said second conduit (103, 203) from corroding; and
 - arranging the first and second temperatures and the first and second flow rates so that a third temperature of the mixed fluids downstream said mixing length (115, 215) is obtained, at which said third fluid being substantially non-corrosive.
23. The method as claimed in Claim 22, characterized by providing at least the inner surface area of said first conduit (107, 207) of a corrosion resistant material.
24. The method as claimed in Claim 23, characterized by that said second fluid contains supercritical wastewater.
25. The method as claimed in Claim 24, characterized by feeding the mixed fluids in said second conduit (103, 203) to the reaction (18) of the high pressure and high temperature reaction system (10) for oxidation of waste material contained in the wastewater.
26. The method as claimed in Claim 25, characterized by that said first fluid contains nitric acid and that said second fluid contains nitrogenous compound.
27. The method as claimed in Claim 25 or 26, characterized by that said second fluid acts as cooling water.
28. The method as claimed in Claim 27, characterized by that said first fluid contains destructed supercritical or subcritical wastewater output from the reactor (18) of the high pressure and high temperature reaction system (10).

29. The method as claimed in any of Claims 22-28, characterized by arranging the tube or liner (105, 205) removably in said second conduit (103, 203).

5 30. The method as claimed in any of Claims 22-29, characterized by arranging the tube or liner (105, 205) so it extends a predetermined distance (117, 217) upstream from where said first conduit ends.

10 31. The method as claimed in any of Claims 22-30, characterized by providing said second conduit (103, 203) with means for holding and/or positioning said tube or liner (105, 205), preferably an elbow (119, 219) at the downstream end of the mixing length (115, 215).

15 32. The method as claimed in any of Claims 22-31, characterized by that at least the inner surface area of the tube or liner (105, 205) is made of a material chosen from the group of titanium, zirconium, platinum, tantalum, niobium and alloys thereof.

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ABSTRACT

In a high pressure and high temperature reaction system, there is provided an apparatus (101, 201) for injecting a first fluid of a first temperature at a first flow rate into a second fluid of a second temperature at a second flow rate, said first fluid being corrosive in a temperature range comprising a first conduit (107, 207) connected and adapted to transport the first fluid, a second conduit (103, 203) connected and adapted to transport the second fluid, said first conduit ending in the interior of said second conduit, thus communicating with said second conduit, whereby a predetermined amount of heat transfer between the first and the second fluids is arranged to occur within a length (115, 215) in said second conduit, and a tube or liner (105, 205) with at least its inner surface area of a corrosion resistant material, said tube or liner being located in, or constituting part of, said second conduit and extending along said mixing length (115, 215) to protect said second conduit from corroding, wherein said temperatures and flow rates are arranged so that a third temperature of the mixed fluids downstream said mixing length is obtained, at which said third fluid being substantially non-corrosive.

(Fig. 2 suggested for publication)

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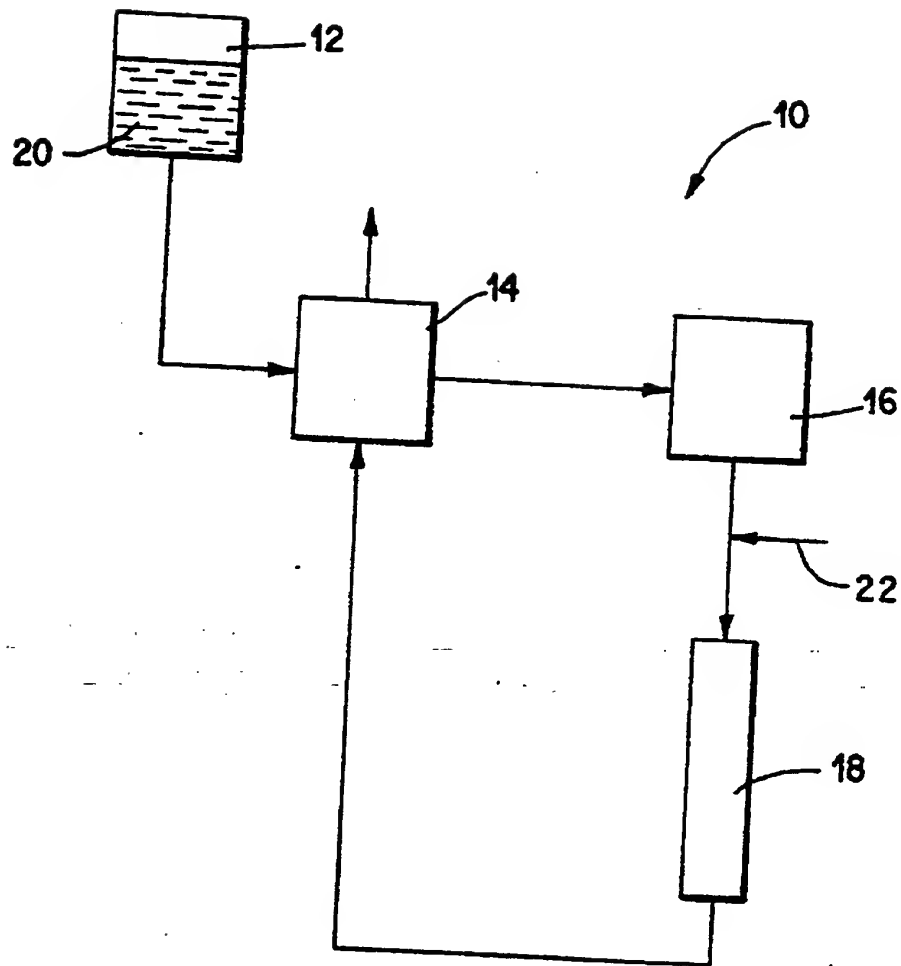


Fig. 1

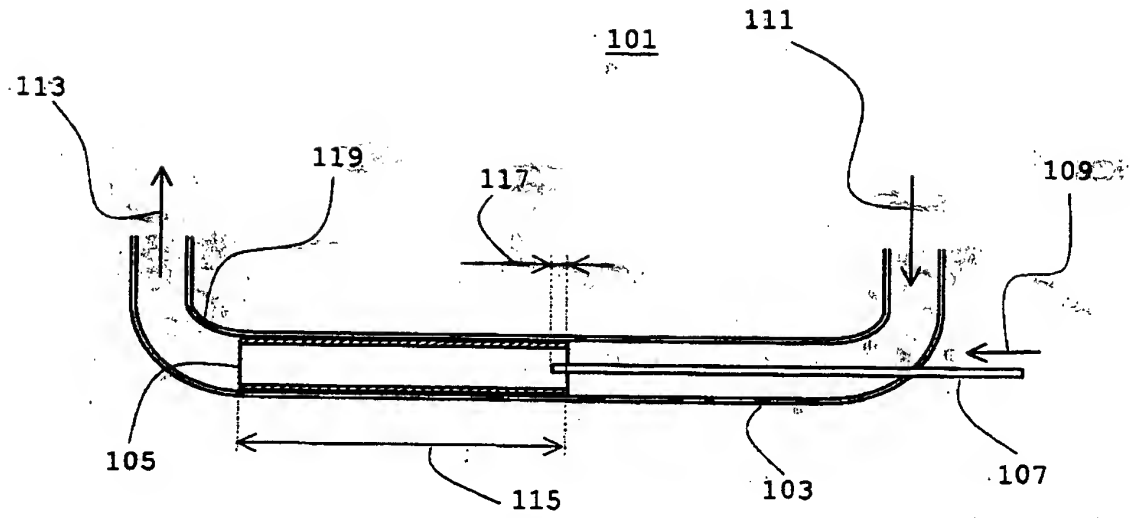


Fig. 2

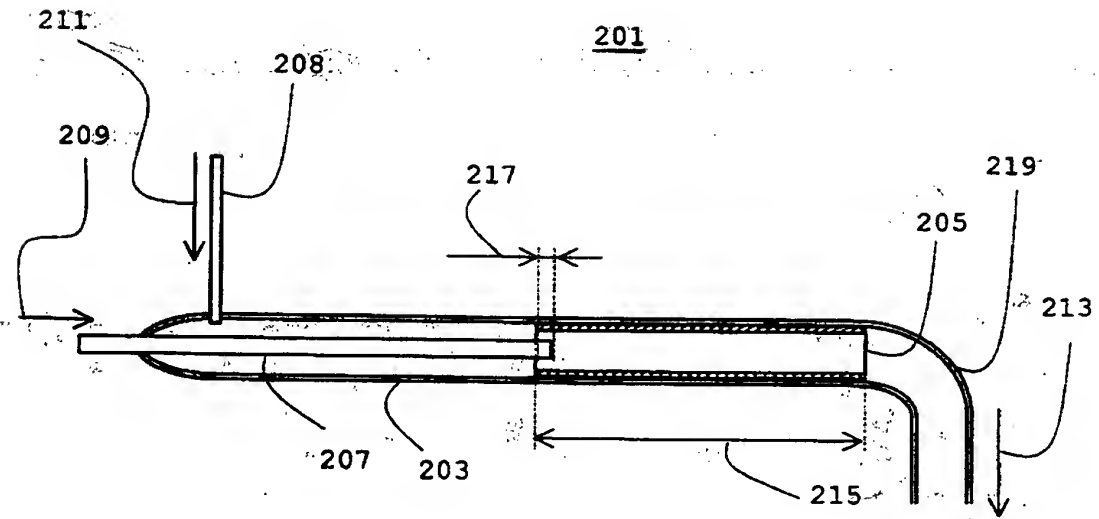


Fig. 3